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Performance Evaluation of Existing Wedgewater and Vacuum-Assisted Bed Dewatering Systems

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This study compiled operational data from commercial WWTPs with existing WBs and VABs to evaluate their potential for Army use. Generally, WBs were found to be easier to operate and maintain than VABs. WBs also showed fewer media- and underdrain-clogging problems when high-pressure hoses were used to clean the media, and when tiles were kept free from damage. VABs were preferred by smaller plants that required a lower target solids rate. Most problems with both systems were associated with poor media cleaning, front-end loader damage, and engineering errors.

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EXECUTIVE SUMMARY

Under the Facilities Engineering Application (FEAP) Program, the U.S. Army Construction Engineering Research Laboratory (USACERL) demonstrated improved sludge-dewatering technologies at Fort Campbell, KY, using wedgewater-bed (WB) and reed-bed technologies. This report summarizes the results of a field survey that analyzed the performance of WBs and vacuum-assisted beds (VABs), and compares the field performance of these two technologies. (A report on the reed-bed technology will be published separately.) Operational data was compiled from commercial WWTPs with existing WBs and VABs to evaluate their potential for Army use. A telephone survey carried out for both WBs and VABs helped identify users of the two technologies as either "satisfied" or "dissatisfied" with their chosen systems. Survey results showed that the wedgewater system can provide essentially the same service as the vacuum-assisted beds, but with fewer operational and maintenance problems.

Generally, wedgewater bed system operators were satisfied with the system's sludge-dewatering capacities. WBs were generally easier to operate and maintain, and provided a quicker turnover rate than sand beds. WBs showed fewer problems with media and underdrain clogging when high-pressure hoses were used to clean the tiles, and when tiles were kept free from damage.

WB solid capture was less than VAB, but additional solid loading of WB filtrate to the head of a plant did not adversely affect plant performance. The wedgewater system provides this degree of dewatering with about one drying cycle per bed per week. Most system problems were associated with inadequate media cleaning, front-end loader damage to the filter media, or engineering errors. It appears that, with proper design, installation, care, and maintenance during operation, the beds will have a long life. Although most WBs were open-air operations, use of a translucent roof or canopy was recommended for areas receiving large quantities of precipitation, or where freezing occurs.

VAB system advantages include a faster turnover rate than sand or wedgewater beds, the ability to operate year-round due to the system's building enclosure, and less space requirement. In total, VABs dewater more efficiently than sand beds, but do not perform as well as wedgewater beds do when only air drying is used. VABs are still more effective than WBs in achieving a target solid range of 11 to 13 percent, because only vacuum can reach these high concentrations. A common complaint against old VABs was that the sludge was not "bladeable" in the predicted time, and therefore required long drying. This problem resulted from inadequate drainage caused by media binding.

For these reasons, a decision was made to build a wedgewater bed rather than a vacuum-assisted bed at Fort Campbell to demonstrate the dewatering technology that requires less space and dewatering time. However, even considering the results of this study, any Army installation considering a dewatering method for new or retrofit application should first do a detailed economic analysis.

FOREWORD

This research was conducted for the U.S. Army Engineering and Housing Support Center (USAEHSC), Fort Belvoir, VA, under Facilities Engineering Applications Program (FEAP) Project FT9, "Improvement of Sludge Dewatering Capability at Army Wastewater Treatment Plants." The technical monitor was Mr. Malcom McLeod, CEHSC-FU.

This study was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (USACERL). The USACERL principal investigator was Dr. Byung Kim. Dr. Raul Cardenas is associated with Carpenter Environmental Associates, Inc., Ramsey, NJ. Dr. Edward Novak is Acting Chief, USACERL-EN. The USACERL technical editor was Mr. William J. Wolfe, Information Management Office.

LTC E.J. Grabert, Jr. is Acting Commander of USACERL, and Dr. L.R. Shaffer is Director.

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PERFORMANCE EVALUATION OF EXISTING WEDGEWATER AND VACUUM-ASSISTED BED DEWATERING SYSTEMS

1 INTRODUCTION

Background

Because of their simplicity, low cost, and applicability to small-scale sludge treatment, many Army wastewater treatment plants (WWTPs) employ conventional sand-drying beds to dewater sludge. The benefits of sand-drying beds, however, must be weighed against the relatively long time to satisfactorily dry sludges; the continuous requirement for manual sludge removal; and the need for a large, dedicated land area. Moreover, outdoor sand-drying beds are vulnerable to adverse weather conditions and operational problems associated with sand-media and underdrain clogging.

Over the years, there have been improvements in sludge processing in both equipment and the use of polymers. Successful technologies used in the treatment of sludge at small-scale wastewater treatment plants include the wedgewater bed (WB), vacuum-assisted bed (VAB), and reed-bed systems.

Although many small municipal and industrial WWTPs operate WB and VAB systems, no systematic performance evaluation or comparison of the two systems has been made. Most small WWTPs build such systems based on vendor's promotional information or on the recommendations of a local architect/engineer (A/E) without further research because small, individual WWTPs cannot afford to compile such information and large plants are not interested in them. As the operator of over 100 small-scale WWTPs, the Army has an interest in such cost-effective and technically efficient sludge dewatering technologies.

This study compiled operational data from existing WBs and VABs at commercial WWTPs, and compared the advantages and disadvantages of both systems to determine which of the two sludge-dewatering systems showed better potential for use at Army installations. The results of this study were used to select a wedgewater bed for installation, along with a reed bed, at Fort Campbell, KY, as a Facilities Engineering Application Program (FEAP) demonstration of WWTP sludge-dewatering technologies appropriate for Army use.

Objectives

The overall objectives of this study were to: (1) compile and evaluate operational data available on wedgewater-bed and vacuum-assisted bed dewatering systems, and (2) analyze the potential for Army use of these systems.

Approach

User lists were obtained from manufacturers' customer lists, and a questionnaire was designed to help conduct a telephone survey of plant supervisors of 27 wedgewater-bed and 28 vacuum-assisted-bed systems, to gather both objective, operational data and subjective evaluations of both systems. A copy of the questionnaire is included in the Appendix to this report.

The questionnaire was divided into 11 areas of inquiry:

1. Identification and description of the plant
2. Plant characteristics
3. Sludge characteristics
4. Dewatering system
5. Dewatering performance
6. Polymer data
7. Cleaning
8. Sludge removal
9. Unit construction costs
10. Problems
11. Remedies and advantages of the system.

To supplement the telephone survey, several (5 wedgewater-bed and 5 vacuum-assisted-bed) sites were visited to survey users of the two technologies. (Because of limited funding, only two plants with "satisfied" operation were visited. These plants were chosen for their proximity to Carpenter Associates.) During site visits, plant supervisors were further interviewed using the areas of inquiry outlined in the questionnaire. Information gathered from the telephone and site interviews was used as a basis for classifying users as either "satisfied" or "dissatisfied" with their present systems, and for selecting which of the two technologies to use in a subsequent FEAP demonstration.

Scope

Note that measures of satisfaction were based solely on plant managers' opinions. Performance evaluation results in this report were similarly based solely on operators' opinion, on the operation of a limited number of WWTPs. Since WWTP and sludge characteristics differ, the Army WWTP manager shall consider site-specific conditions before applying the study results in this report to select or upgrade a dewatering system. It was beyond the scope of this report to evaluate specific commercial products; investigators were interested in general operation data only.

This report focuses on wedgewater-bed and vacuum-assisted bed systems. It is anticipated that a report summarizing reed bed performance will be published separately.

Mode of Technology Transfer

A Facilities Engineering Applications Project (FEAP) report, and a technical note on reed and WB systems will be prepared after 2 years of reed bed operation at Fort Campbell, KY.

2 THE PROCESSES

Both WB and the VAB systems are generally used by small WWTPs to dewater polymer-conditioned sludges prior to final disposal.

Wedgewater Bed

Wedgewater, or wedgewire beds, as they are sometimes called, are proprietary devices that use either an interlocking polyurethane panel media or stainless-steel septum (separating) media as a filtering surface, which is perched on a concrete basin. The processed sludge with added polymer is placed on the surface for drainage and dewatering. The polyurethane media essentially comprises a box with a false bottom; the space below the media allows underdrains to collect and remove the water that percolates through the sludge and the media. The stainless steel type of media requires additional support because the media is too thin to allow free flow of drained water beneath the media.[1] Figure 1 shows a polyurethane media. Figure 2 shows a cross section of the wedgewater bed using a stainless steel septum media consisting of many triangular-shaped wires.

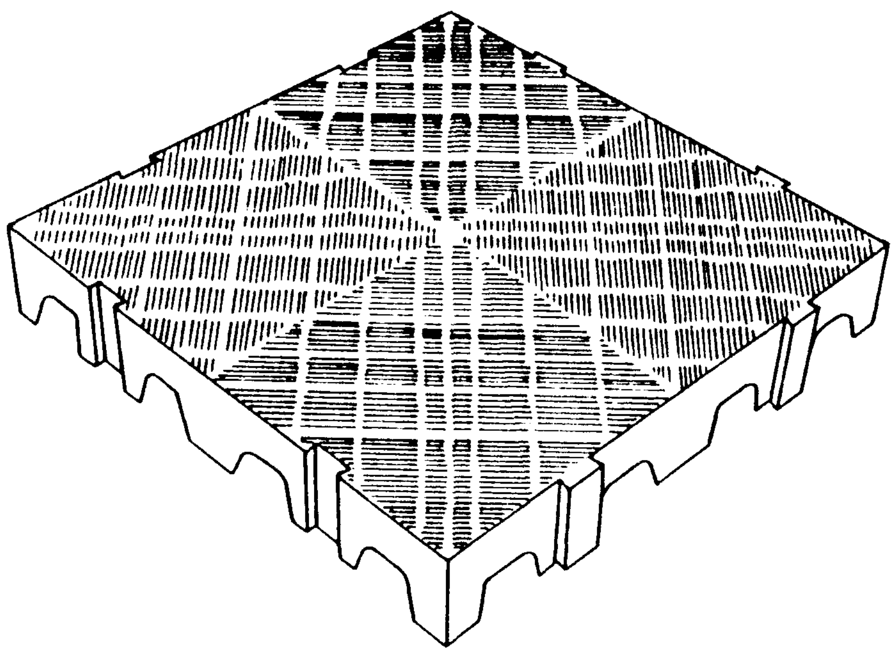


Figure 1. Polyurethane Wedgewater Bed Media Unit.

[1] *Design Manual, Dewatering Municipal Wastewater Sludges*, EPA-625/1-87/014 (U.S. Environmental Protection Agency [USEPA], 1987); *Process Design Manual for Dewatering Municipal Sludges*, EPA-625/1-82/014 (USEPA, 1982).

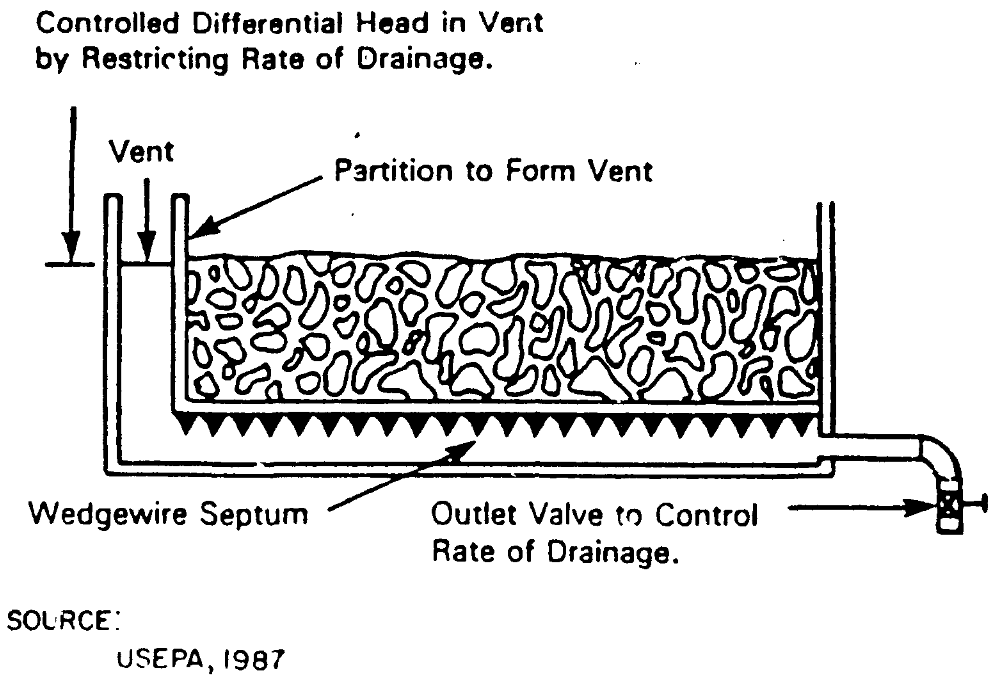
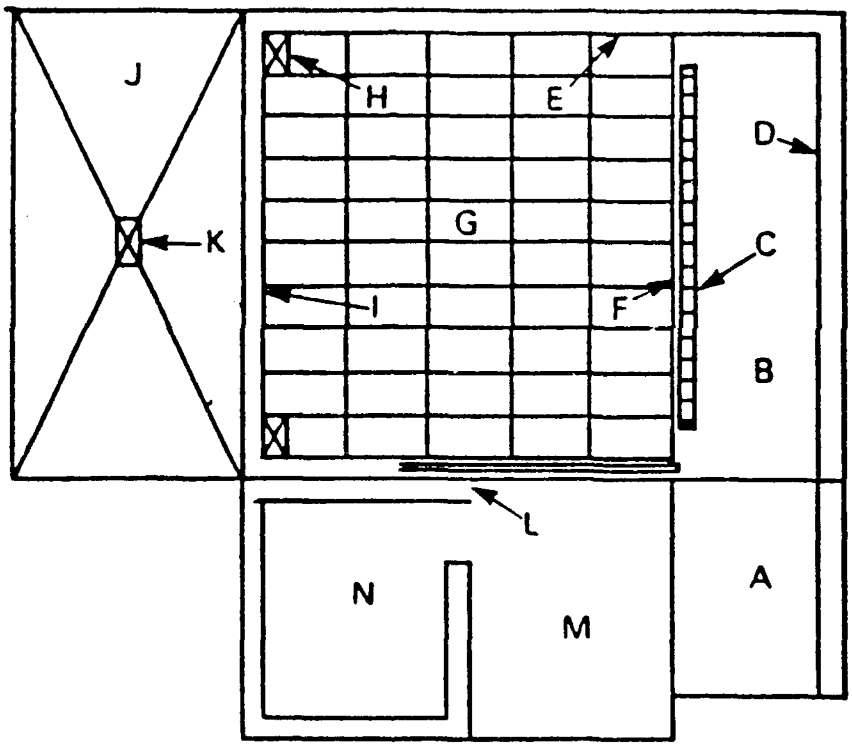


Figure 2. Wedgewater Bed Schematic.

Vacuum-Assisted Bed

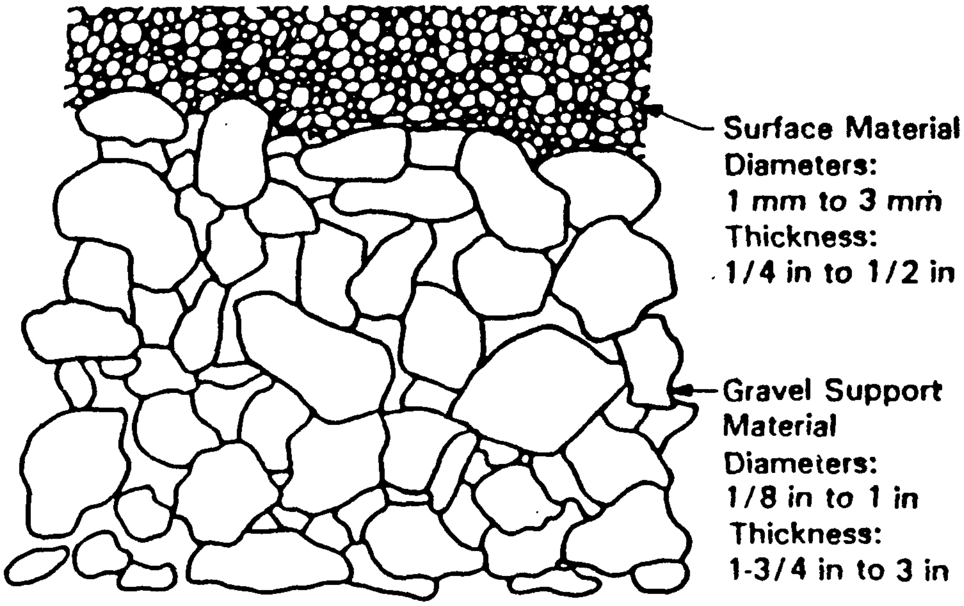
VABs are also proprietary sludge dewatering units that employ an epoxied, porous, rigid-media filter plate, comprised of a carborundum surface and gravel support material. The media is placed above a level, supporting concrete slab or graded stone, overlying a sloped concrete slab as drainage structure. Polymer-conditioned sludge is placed on the surface and a vacuum is applied to the sludge and media to assist in drawing water through the plate. Figure 3 shows a schematic view of a vacuum-assisted drying bed. Figure 4 shows a cross-section of the VAB media.



A. Entrance Ramp
B. Off-Bed Level Area
C. Area Drain
D. Curbing
E. Sludge Distribution Piping
F. Bed Closure System
G. Media Plates
H. Corner Drain
I. Bed Containment Wall
J. Truck Loading Area
K. Area Drain
L. Wash Water Supply
M. Sludge Feed Inventory Tank (below grade, seldom required)
N. Control Building with
- Sludge Feed Pumps
- Polymer System
- Vacuum Pumps
- Control Panel
- Filtrate Receiver/Pumps (below grade)

SOURCE:
USEPA, 1987

Figure 3. Schematic View of Vacuum-Assisted Dewatering Bed Media.



SOURCE:
USEPA, 1987

Figure 4. Cross-Section of Vacuum-Assisted Dewatering Bed Media.

3 RESULTS OF SURVEY

After categorizing the users of the two dewatering systems as "satisfied" or "dissatisfied," each group was queried in the 12 outlined areas. This chapter summarizes their responses.

Wedgewater Bed

Identification of Plants

All the users of the wedgewater process in this report are small municipalities except for one food-processing industry. The majority of users are located in the eastern United States. Table 1 lists the names of the plants, locations, points of contact, and telephone numbers of wedgewater system users.

A total of 27 users were surveyed, further classified into 20 satisfied and 7 dissatisfied users. (This report does not identify satisfied or dissatisfied by name.)

Plant Characteristics

Table 2 summarizes plant characteristics for satisfied and dissatisfied users. Plant characteristics examined include: plant capacity, treatment process used, sludge digestion process employed, and final disposal method.

Average plant capacity for all plants was found to be 2.22 mgd (million gallons per day).* However, many surveyed plants operate well below capacity. The capacity of flow for all of the plants ranged from 0.07 to 8.8 mgd. Nine plants had less than 1 mgd capacity. For satisfied users, the range of flow was from 0.09 to 7.5 mgd. For dissatisfied users, the range of flow was from 0.07 to 8.8 mgd. For satisfied users, average flow was 1.7 mgd. For dissatisfied users, average flow was 3.5 mgd, about twice the flow of satisfied users.

In all, 23 users employed the activated sludge process, three employed fixed films (two trickling filters and one rotating biological contactors), and one used a dissolved-air flotation (DAF) cell in a secondary treatment process. Of the satisfied users, 18 employed the activated sludge process, one used the DAF cell and one used fixed film. Of the dissatisfied users, five employed activated sludge and two used trickling filters.

The majority of the users of wedgewater sludge treatment units processed sludge using aerobic methods. Fifteen plants employed aerobic sludge digestion, five used anaerobic digestion, and seven did not process their sludge prior to dewatering by the wedgewater method. Of the 20 satisfied users, 11 preferred aerobic digestion, two employed anaerobic digestion, and seven did not further process their sludge. Of the seven dissatisfied users, four used aerobic digestion and three employed anaerobic digestion.

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*A metric conversion table is included on p. 48.

Table 1

Wedgewater Bed Contact Information

Identification of Plant	Location	Point of Contract	Telephone No.
Auburn Wastewater Treatment Plant	Auburn, IN	Bruce Schlosser	219-952-1714
Baldwin Regional Treatment Plant	Baldwin, FL	Jack LaLonde	904-266-9055
Buena Ventura Lakes WWTP	Kissimmee, FL	Mike Johnson	407-348-4855
Camel WWTP	Indianapolis, IN	Owen Lee	317-844-2394
Central Boaz Pub. Serv. Dist.	Parkersburg, WV	Dave Radabaugh	304-375-4803
Chesterton	Chesterton, IN	Ms. McDonald	219-926-1032
City of Atlantic Beach STP	Atlantic Beach, FL	Tim Townsend	904-249-7337
City of Kingston WWTP	Kingston, TN	John Moates	615-376-2901
City of Montezuma WWTP No. 2	Montezuma, GA	Butch Cofer	912-472-8101
City of Paden City WWTP	Paden City, WV	Larry Titus	304-337-8521
City of Tarpon Springs WWTP	Tarpon Springs, FL	Dave Gilleo	813-938-3711
Cullman WWTP	Cullman, AL	Jerry Paul	205-739-2410
Fast Food Merchandisers	Monterey, TN	Gary Griffin	615-839-2273
Friendly Public Service District	Friendly, WV	Dave Gorrell	304-652-1401
Gulf Shores WWTP	Gulf Shores, AL	Allan Sizemore	205-968-7736
Harry Still, Sr. WWTP	Bay Minette, AL	Dennis Lamberth	205-937-2820
Hohenwald WWTP	Hohenwald, TN	Paul Webb	615-796-3850
Hallstead-Great Bend JSA	Great Bend, PA	Bill Burchell	717-879-2994
Island Bay Utilities	Orange Beach, AL	Terry Cawthron	205-918-6096
Kanawha Falls PSD	Gally Bridge, WV	Mike Cenati	304-779-2855
Matewan WWTP	Matewan, WV	Mike Preston	304-426-8553
Mismisburg WWTP	Miamisburg, OH	Ron Bunger	513-866-3303
North Kuhler Road WWTP	New Braunfels, TX	John Toelier	512-625-0258
Petersburg WWTP	Petersburg, WV	Lloyd Britewell	304-257-1127
Saint City WWTP	Chalmette, LA	Steve Lombardo	504-271-1681
Siler City WWTP	Siler City, NC	Fergus Brown	919-742-4581
Wichita Falls WWTP	Wichita Falls, TX	Clay Ham	817-766-2841

Table 2

Wedgewater Bed Plant Characteristics

Plant ID	Plant Capacity (gal/day)	Treatment Process	Sludge Digestion Process	Final Disposal Method
Satisfied				
1	3,300,000	Activated sludge	Anaerobic	Land application and storage
2	400,000	Activated sludge	Aerobic	Landfill
3	1,300,000	Activated sludge	Aerobic	Land application
4	90,000	Activated sludge	None	Landfill
5	2,000,000	Activated sludge	Aerobic	Landfill
6	1,000,000	Activated sludge	Aerobic	Landfill
7	2,000,000	Activated sludge	None	Land application
8	1,600,000	Activated sludge	None	Landfill
9	4,000,000	Activated sludge	None	Land application
10	350,000	DAF cell	Aerobic	Landfill
11	100,000	Activated sludge	None	Land application
12	3,000,000	Activated sludge	Aerobic	Landfill
13	2,000,000	Activated sludge	None	Landfill and land application
14	1,100,000	Activated sludge	Aerobic	Landfill (using as cover)
15	375,000	Activated sludge	Aerobic	Landfill
16	1,600,000	Activated sludge	None	Landfill
17	125,000	Activated sludge	Aerobic	Landfill
18	350,000	RBC units	Aerobic	Landfill
19	7,500,000	Activated sludge	Anaerobic	Land application
20	3,100,000	Activated sludge	Aerobic	Landfill
Dissatisfied				
1	8,800,000	Activated sludge	Anaerobic	Land application and storage
2	2,700,000	Activated sludge	Anaerobic	Land application and storage
3	4,750,000	Trickling filter	Anaerobic	Land application
4	600,000	Activated sludge	Aerobic	Landfill, land application
5	5,870,000	Trickling filter	Aerobic	Landfill
6	1,800,000	Activated sludge	Aerobic	Landfill
7	70,000	Activated sludge	Aerobic	Landfill and composting

The most common final disposal method was by landfill. Fifteen of the surveyed plants used landfilling as the sole method of final disposal, six used land application or land spreading, and six combined land application with landfilling, storage, or even composting. Thirteen satisfied users employed landfilling and only five used land application for final disposal, while two plants used a combination of landfilling, land application, and temporary storage.

Two dissatisfied users used landfilling; one used land application; and four employed varying combinations of land application, storage, landfilling, and composting.

Sludge Characteristics

Table 3 lists the sludge characteristics found during the survey. The average percent solids processed for all respondents to the question was found to be 3.4 percent, in a range of 1.5 to 7.0 percent. Responding satisfied users averaged 3.4 percent solids in a range of 1.5 percent to 7.0 percent and dissatisfied users averaged 3.5 percent, ranging from 2.0 percent to 6.0 percent.

Operators were not always able to determine the sludge generation quantities. In all, 18 users responded and nine did not. As Table 3 indicates, users provided generation quantity in various units. The majority responded in units of weight (dry or wet ton or pound) per year, per week, or possibly per month. Some results were quoted by volume (cubic feet or gallons). To create a meaningful comparison, generation quantities were converted to dry ton/year/plant capacity (mgd). Four plants reported generation volume without percent solids and, therefore, dry ton/year/mgd figures could not be derived. The range of 14 plants was 26 dry tons/yr/mgd and the average weight was about 100 dry ton/yr/mgd. A typical 1 mgd activated sludge plant with an anaerobic digester produces 360 dry ton/yr.[2] The discrepancy between these figures was attributed to the fact that actual flow at these plants was much less than their design capacity, and influent biological oxygen demand (BOD) and suspended solids (SS) were less than typical 250 mg/l, from which the 360 dry ton/yr/mgd figure was derived.

Dewatering System Data

Characteristics associated with dewatering are summarized in Table 4.

Most of the plants had only a few wedgewater beds in use. For example, 19 plants had fewer than five beds, and eight plants had five or more beds. Most beds ranged from 600 to 1200 sq ft. The largest was 5000 and the smallest was 168 sq ft.

Most wedgewater dewatering systems at surveyed plants are no more than 5 years old, and most of the operations are carried out outdoors, some with a roof. Only six plants had beds located inside buildings.

Design loading rates per operational cycle were hard to obtain. Actual solid loading ranged from 1.5 to 3 lb of dry solids per sq ft of bed. Hydraulic loading was 500 gal average design flow per sq ft of the bed. Using the criteria, 1 mgd plant would need 2000 sq ft of wedgewater bed.

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[2] Vesilind, Aarne, *A Treatment and Disposal of Wastewater Sludges* (Ann Arbor Science Publishers, Ann Arbor, MI, 1979).

Table 3

Wedgewater Bed Sludge Characteristics

Plant ID	Average % Solids	Target Solids	Generation Volumes	Special Characteristics
Satisfied				
1	7.0	20%	412 t/yr	Typical
2	1.5		-180 lb/day	Typical
3	2.0	20%	1.5-2 t/day	High phosphorus, copper
4	5.5		Unknown	Typical
5	3.3	15-18%	236,000 gal/mo	Typical
6			Unknown	Typical
7			Unknown	90% vol vegetative matter (frozen foods)
8			5 t/wk	Typical
9	6.0	14-30%	8-10 t/day (est)	Typical
10			Unknown	High nitrogen (plant drain water)
11			50-60 lb/day	Typical
12	1.5	9%(8-12%)	23,811 lb wasted in Sept 1989	High manganese (potassium formanganate previously used for color control)
13	3.0	14%	3 t/wk	Creosote byprod/wax
14	2.0	17-18%	0.8 t/mo	Typical
15		20%	Unknown	Typical
16	2.5		8-9 t/wk	Typical
17			Unknown	Typical
18	5.5		1000 cu ft/wk	Typical
19	2.5	18-35%	Unknown	Typical
20	1.8	16%	15 t/wk	Typical
Dissatisfied				
1	3.7		Unknown	Typical
2	4.5	14-15%	-1020 lb/day	Typical
3	6.0		122 t/yr	Typical
4	2.5	20%	20,000 lb/mo	100 lb organic nitrogen/t of sludge
5	4.0	12%	10 t/wk	Typical
6	2.0		20 cu yd/mo	Typical
7	2.0	10-15%	Unknown	Typical

Table 4

Wedgewater Bed System Data

Plant ID	Number of Beds	Size of Beds(1)	Construction Year	Predicted Life Cycle	Type of Exposure	Design Loading
Satisfied						
1	2	20×40 ft	1982		Translucent fiberglass building	4 lb/sq ft
2	1	~1000 sq ft	1988		Open air	2 lb/sq ft
3	4	400 sq ft	1985&88	20+ yr	Open air	1.5-2 lb/sq ft
4	2	482 sq ft	1988	10 yr	Open air w/roof	
5	4	28×28 ft	1983&87		Open air	1 lb/sq ft
6	2	20×40 ft	1988		Open air	
7	2	1800 sq ft	1985		Open air w/roof	2 lb/sq ft
8	4	25×30 ft	1987		Open air w/roof	
9	5	60-80×24 ft	1986		Open air	
10	2	30×15 ft	1987		Open air	
11	2	14×12 ft	1984		Building	
12	4	50×25 ft	12/87		Open air	2.25 lb/sq ft
13	3	25×50 ft	1984	10 yr	Open air	
14	2	25×40 ft	1987		Open air	2 lb/sq ft
15	2	15×15 ft	1987		Building	
16	3	(1) 30×40 ft (2) 30×50 ft	1984 1988	20 yr	Open air	
17	6	25×18 ft	1981		Ventilated fiberglass building	8-10 in.;8-12% sq
18	2	12×50 ft	1984		Open air	1100 cu ft
19	5	1288 sq ft	1988	15-20 yr	Open air w/roof	12,400 gal/bed
20	5	2560 sq ft	1985		Open air	3 lb/sq ft
Dissatisfied						
1	20	No response			Open air bldg.	35,000 gal/bed
2	4	25×40 ft	1989		Building	4 lb/sq ft/day
3	2	30×60 ft	1984		Open air	
4	4	2080 sq ft	1987		Partially open bldg.	1.5 lb/sq ft
5	8	1000 sq ft	1988		Open air	2 lb/sq ft
6	2	50×100 ft			Open air	
7	6	32×51 ft	1988		Open air	25,000 gal/bed

Dewatering Performance Data

Dewatering bed performance for wedgewater units is shown in Table 5. Initial sludge depths reported were mostly in the range of 10 to 18 in., but some initial depths were less, and at least one or two plants reported initial sludge depths of 24 to 36 in. Final sludge depths were generally reported to be in the range of 4 to 6 in., although some depths were reported to be 18 to 24 in.

The dewatering cycle consists of drainage and air drying. There is no universally recognized definition of drainage time. Drainage time may be defined as the duration from the completion of sludge pouring into the bed, to the completion of filtrate generation. Drainage times varied widely, from an estimated 30 min to 48 hours. In general, draining was complete in under 10 hours. Air-drying time was usually reported to occur in a few days, although one plant reported an air-drying time of 6 months. Plants with infrequent loadings had the luxury to let the sludge sit on the beds until the next loading. Air-drying time may also be defined as the duration from the end of drainage to the time when solid content reaches about 20 percent. Most plants reported 0.5 to 2 dewatering cycles per week, with an average of about one drying cycle per week. Actual drying cycles depend on both the sludge dryness required by the landfill and the plant's sludge loading rate.

Polymer Data

Table 6 shows that a variety of polymers are used to condition sludges before applying to the wedgewater system. Polymer varieties and dosages are plant-specific and must be adjusted to fit the particular sludge characteristics of a plant.

Polymer dosage was reported in a variety of units, and operators often reported polymer dosage in terms of volume of polymer per bed. For example, from 2 to 5 gal per bed were typical polymer dosages. Since bed size and sludge depth differ, the unit used to measure polymer dosage was gallons of polymer per dry ton of sludge. The polymer dosage varied from 1.2 to 10 gal per dry ton sludge, and average was 5 gal per ton. Typical polymer used in the estimation was an emulsion type with 40 to 60 percent active ingredient. By comparison with the polymer dosage suggested by the U.S. Environmental Protection Agency (USEPA), the dosages in this survey were about twice of the typical dosage.

Table 6 also shows polymer costs, which appear to range from $1.50 to $2.00 per lb. Average polymer costs were $800 per 55-gal drum.

It should be noted that 11 plants, or 41 percent of those surveyed, used no analytical methods to measure polymer dosages, but visually observed the polymer dosages and adjusted dosage amounts for effectiveness.

Cleaning Data

Table 7 shows that wedgewater beds are most often cleaned with water using high pressure hoses after each cycle. Duration of the cleaning cycle varies from 15 min to 3 or 4 hours, but a typical cycle appears to be about 1 hour per 1000 sq ft bed. It should be noted most dissatisfied plants either did not report the cleaning duration, or did not use high-pressure water hose.

Table 5

Wedgewater Bed Performance Data

Plant ID	Depth of Sludge (in.) Initial	Final	Drainage Time	Air Drying Time	Drying Cycle Per Week
Satisfied					
1	18	12-14	-	-	1
2	6	<1	~6 hrs	1-4 wks	1-2/month
3	16	4-6	-	1-5 days	2-3/bed
4	12	4	1.5-2 hrs	4-7 days	1
5	30-36	18-24	"Right away"	4 hrs	1 bed/month
6	-12	4-6	24 hrs	3 days	1 bed/month
7	12-15	4-6	3-4 hrs	24 hrs	2-3
8	12-16	1.5-3.5	<5 hrs	-	3/month
9	6-7 or 18-24	4-6	-	1-2 days	3/2 beds
10	1-8	0.5-6.5	30 min-1 hr	1-7 days	2-4
11	12-24	4-7	2-10 hrs	-	2-4
12	8-12	2-4	-	2-3 days	1/bed
13	18	2	-	3 days	1/bed
14	12	8	1 hr	3-10 days	0.5-1
15	12 1 at removal	4-5 after 24 hrs	-	1.5-2 mos *	1/1.5-2 mos *
16	16	6	-	2 days	1
17	12	1.5-2	1 hr	6 hrs	1
18	8-10	1.5	-	<5 hrs	1
19	3	1	-	~4 days	1/2 wks
20	16	8-9	-	24-36 hrs	5
Dissatisfied					
1	12	0.5	-	6 mos	1/6 mos
2	18	8	-	3 days	2
3	8	-	2 days	1-2 wks	2 (every other wk)
4	10-12	1.5-2	-	10-12 days	1/10 days
5	10	5	-	3 days	1/bed
6	10	4	1 day	1 wk	1
7	12	1.5-2	1 day	2-3 days	1-3

* Not really applicable - must dry until it meets landfill standards

Table 6

Wedgewater Bed Polymer Data

Plant ID	Name of Polymer	Manufacturer's Name	Polymer Dosage	Cost of Polymer
Satisfied				
1	Mid Floc 58-23E	Mitco	17 gal/bed	$1.44/lb
2	LC-804	Leah Chem Industries	Visual adjust	-
3	LC-902N	Leah Chem Industries	Unknown	$1.64/lb
4	KR033	Unknown	Unknown	-
5	LC-902N	Leah Chem Industries	36 gal (undiluted)/236,000 gal sl	$1.30/lb
6	H777	Nalco	3.5 gal/bed	-
7	T829L	Chem-Treat	Unknown	$1.15-1.20/lb
8	Unknown	Polymer Systems	1 lb/380 cu ft	$3.90/lb
9	757	Allied Colloids	Unknown	$12-16/2 beds
10	Unknown	Leah Chem Industries	1 gal/bed	-
11	7139	Nalco	3.5-4 gal/both beds	$700/55 gal drum
12	K133L	Stockhausen	2 gal/10,000 gal sl; 1 gal/8lb sl	$1.88/lb
13	K155L	Stockhausen	2 gal/t	$1.90/lb
14	Magnaflo 1596C	Simoned	2.5-3 gal/bed (25-30%)	$2.18/lb
15	Unknown	Unknown	Visual adjust	$1000/55 gal drum (est.)
16	71-25	Nalco	5 gal/bed	$1.87/lb
17	K122L, Praestol	Stockhausen	Unknown	$1.80/lb
18	1501-Magnafloc	Unknown	7-8 gal/min (diluted) to 120 gal/min sl	$850-900/55 gal drum
19	Chemloop K1586 MK	Unknown	Unknown	Unknown
20	Magnafloc 5254	Maint. Eng Corp	2lb/cycle at 33 ppm	$1.65/lb
Dissatisfied				
1	None	N/A	N/A	N/A
2	Clarifloc C-3061	Polypure	5 dry lb/bed	$2.65/lb
3	Unknown	Unknown	Unknown	-
4	750M	Secodyne	2 gal/2500 gal sl	$.185/lb
5	Unknown	Cyanamid	5 gal/bed	-
6	Selflox 1438	Southeast Labs	Unknown	$1.20/lb
7	Applied Specialty 3212	Unknown	<4 gal/bed	$1.80/lb

N/A = Not Applicable

Table 7

Wedgewater Bed Cleaning Data

Plant ID	How Cleaned	How Often	How Long
Satisfied			
1	2-in. hose, water	Each cycle	30 min.
2	Hose w/water	Every "few times"	-
3	Hose/50-55-psi hose	Each cycle	10-15 min.
4	High press. water hose	Each cycle	30 min.
5	1.5-in. water hose & hypochlorine wash	Each cycle	1-2 hr
6	3-in. water hose	Each cycle	4 hr
7	High-press. water hose	1 bed/wk	3-4 hr/bed
8	High-press. water hose	Each cycle	15-20 min.
9	High-press. water hose	Each cycle	2 hr
10	High-press. water hose	Each cycle	45 min.
11	Water hose & semi-annual hypochlorine wash (water hose)	Each cycle	0.5-2 hr
12	High-press. water hose & flood beds	Each cycle Every other time (high-press. hose)	20-40 min. (hose); 20-30 min. (flood)
13	Fire hose; fire hydnt	Each cycle	1.5 hr (sludge removal incl.)
14	High-press. water hose; Sweep mechanism	Each cycle	4-5 hr/bed
15	Hose/press.-water wash	Each cycle	2.5 hr
16	Fire hyd. water hose & underdrain cleaning	Each cycle (hose) Semi-annually	5-6 hr
17	High-press. water hose	Each cycle	30 min.
18	High-press. water hose	Each cycle	20 min.
19	Effluent press water hose & sweep	Each cycle	1-2 hr/bed
20	Plant water & fire hose (50 psi)	Every 5th pull	10 min.
Dissatisfied			
1	Shovel & rake	Each cycle	-
2	Water hose	Each cycle	-
3	Water hose & shovel	Each cycle	-
4	Plant water & pressure washer	Each cycle	1 hr/bed
5	Firehose	Each cycle	>2 hr
6	Not cleaned; just leveled	-	-
7	Water hose, then dry completely	Every 48 hr	-

Sludge Removal Method

Table 8 shows that the most common way to remove sludge from wedgewater beds is to use a front-end loader. Survey responses show that some plants used plastic-covered blades on the loaders to minimize tile damage. Table 8 also shows the variety of loaders employed. Experience showed that skid-type bobcat may damage the media. The survey also indicated that hand shoveling (in about 30 percent of the location) was often used to assist in sludge removal, and, in one case, a conveyor was used. However, hand shoveling was used in plants processing less than 1 mgd.

Unit Construction Costs and Warranty

Unit construction costs were not generally available (Table 9). Available data records costs ranging from $74,000 to $425,000 (with a building). Unit costs by area varied from $35 to $300 per sq ft of media. Lower costs were usually associated with conversion of old sand beds to the wedgewater system, using plant personnel for routine construction tasks. Higher costs involved the cost of outside contractors, new construction materials, and the cost of building an enclosure. Warranty periods for wedgewater installations typically extend for 1 year.

Problems

Table 10 lists problems and remedies encountered with wedgewater sludge dewatering beds.

Generally, problems encountered during wedgewater operation were: Design and engineering problems (e.g., beds too low for the front-end loader, underdrains above floor level, small bed capacity, uneven sludge distribution, undersized polymer feed pump, etc.), media damage from front-end loaders and bucket, solids accumulation beneath the media, overly labor-intensive operation, and high cost of media replacement. Solid accumulation beneath the media was a problem because solids smaller than the slot opening of 0.015 in. passed. An even smaller slot opening would have increased solid capture, but might have caused a clogging problem. The manufacturers claimed that the high density, ultraviolet-resistant polyurethane may last 10 years, but no empirical data is available on actual media life since the beds were built less than 10 years ago.

Advantages of the System

Table 11 lists the perceived advantages of wedgewater sludge dewatering beds. In many instances plant operators compared wedgewater plants to sand-drying beds. Wedgewater beds require much less area than do sand-drying beds. If the (EPA design manual) sand-drying bed requirement of 1.5 sq ft per capita were compared to the estimate of wedgewater bed requirement of 2000 sq ft per 1 mgd wastewater, the wedgewater area requirement would be 1/7.5. (assuming 100 gal per capita). Among the noted advantages of wedgewater beds over sand-drying beds were: faster turnover rate; reduced drying time; greater cost effectiveness (lower labor costs, ease of operation and maintenance, and absence of sand replacement); less susceptibility to clogged drains than both sand beds and VABs; ability to operate independently of weather; less media clogging; and less operational costs than with a belt press, filter press, or centrifuge. WBs also compared well with VABs: WBs give no clogging problems and need fewer mechanical part replacements such as vacuum pumps.

Table 8

Wedgewater Bed Sludge Removal Method

Plant ID	Front End Loader Type	Weight
Satisfied		
1	Bobcat	4800 lb
2	No loader-hand shoveled	-
3	No loader-hand shoveled	
4	No loader-hand shoveled	-
5	Ford Kubota 35SS w/#1720 Bucket	<1 ton
6	Ford 77OD Tractor & hand shoveled	-
7	Yarmar w/4 ft bucket	2500-3000 lb
8	Ford 19-horse diesel	-
9	John Deere tractor with bucket	3 or 4 ton
10	No loader-hand shoveled	-
11	No loader-hand shoveled	-
12	John Deere tractor	-
13	John Deere front-end loader	1500 lb, est.
14	John Deere 755; modified	-
15	No loader-hand shoveled	-
16	John Deere 655	-
17	No loader-hand shoveled & conveyor belt	-
18	Terra Mat with blade	Under 2000 lb
19	Small John Deere tractor	-
20	Clark Bobcat	<4900 lb
Dissatisfied		
1	Bobcat	-
2	Bobcat	-
3	No loader-wheelbarrow & hand shoveled	-
4	John Deere 750 Tractor w/Loader	-
5	1100 Ford	<2000 lb
6	Bobcat and hand shoveled	-
7	Skidsteer	~1500 lb

Table 9

Wedgewater Bed Unit Construction Costs and Warranty

Plant ID	Construction Costs	Warranty Period
Satisfied		
1	$130-135,000	Unknown
2	Unknown	Unknown
3	$80,000	Unknown
4	Unknown	1 yr
5	$35/sq ft tile	1 yr
6	Unknown	1 yr
7	$420,000 (est.)	Unknown
8	Unknown	1 yr
9	Unknown	2 yr (est.)
10	Unknown	1 yr
11	Unknown	4 yr
12	Unknown	1 yr (est.)
13	Unknown	1 yr
14	$74,000	1 yr
15	Unknown	1 yr (est.)
16	$45/sq ft of tile	1 yr
17	$425,000 (w/bldg)	1 yr
18	$300/tile	Unknown
19	Unknown	1 yr
20	<$300,000	1 yr
Dissatisfied		
1	Unknown	Unknown
2	Unknown	1 yr
3	$88,000/bed	Unknown
4	Unknown	1 yr
5	Unknown	1 yr or less
6	Unknown	Unknown
7	Unknown	1 yr

Table 10

Wedgewater Bed Problems and Remedies

Plant ID	Problem	Remedy
Satisfied		
1	Damage to media from Bobcat. Underdrain requires occasional cleaning-bleed through from top. Underdrains above floor level.	Use payloader (smaller) and change angle of ramp. New tile may be tougher. Splash plate to direct fall of sewage so it does not hit media directly (will not bleed through as much). Put drains in below floor level.
2	Contractor did not seal digester properly. No calibration kit with polymer. Tiles shifted, leaving a 1-in. gap.	Drained and resealed digester. Increased size of angle iron around edges to close gap.
3	Openings do not facilitate use of tractor. Media must be removed every couple of months to clean solids accumulation. Prefers enclosed facility as beds subject to weather.	Make one side of beds removable.
4	None	
5	Vendor did not give enough information and support. Took 6 months to 1 year to design a workable system.	Plant personnel had to figure out drains required, tractor operation, strips on edges, cleaning method, polymer dosage, and application method for 1st 2 beds. Second set was designed and installed this way.
6	Longer washdown time than expected. Solids accumulation under media after 6 months.	Allow 4 hrs for washdown to prevent solids accumulation.
7	Necessity of replacing tiles; Damaged tile allows sludge through and clogs drainage.	Put in asphalt so loader does not pick up gravel.
8	Blade catches tiles, stainless steel edging	Keep blade perpendicular; tractor operator awareness.
9	Labor intensive to clean.	
10	Hard to clean media when sludge dries. Lots of damp misty days; subject to weather. Outgrew existing beds quickly; plant expansion.	Wash every cycle. Recommends covering beds. Installing centrifuge system.
11	Inadequate ventilation.	Install skylights or leave sides open or install
12	Tile damage by loader bucket. Must be careful of flashing. One row of tiles sticks up and gets caught on loader.	Plastic blade for bucket. Care with angle of bucket/experienced operator.
13	None	

Table 10 (Cont'd)

Wedgewater Bed Problems and Remedies

Plant ID	Problem	Remedy
14	Solids accumulate under media (No cut off valve to allow beds to be flooded). Did not allow enough on each side for media expansion.	Cleanout of underdrains. Took off 3/4 in. media on each side for expansion.
15	None	
16	None	
17	Beds installed 3 ft below grade by engineer.	Bought conveyor belt; will raise beds to floor level, so can use Bobcat.
18	Polymer feed pump undersized. Rainfall moistens sludge again. Cannot flush sludge feed pipes (hence initial sludge applications are septic).	Bigger pump-Variable feed. Will cover plant.
19	Hold down plate shifted during winter. Tiles damaged. Birds roost.	Removed plate and adjusted. Replaced tiles.
20	Solids under media ("Not a real problem")	Normal maintenance washing
Dissatisfied		
1	Drainage system does not work properly	Hoses and tiles replaced.
2	Not dewatering after 3 hr. Possible problem with polymer.	Trying a new polymer.
3	Too labor intensive	
4	Tile shrinkage/expensive replacement. Replace tiles. Solids accumulate underneath. Pressure washing. Slower than existing sand beds (b/c of building?).	Replace tiles. Pressure washing.
5	Poor dewatering. Tiles get torn apart. Hard to clean underdrain. Solids accumulation in surface tile grooves and underdrain. Labor intensive for cleaning.	Keep underdrain clean. Take tiles out every 2-3 loadings, clean w/ shovels.
6	Subject to weather, too wet - sludge not "bladeable."	Remove with shovels.
7	Underdrains clog. Values leak. Subject to weather. Sludge piles up near discharge line; uneven distribution. Polymer expensive. Flashing catches on front end loader.	Pour with underdrain open.

Table 11

Wedgewater Bed Advantages

Plant ID	Advantages
Satisfied	
1	Can process more sludge; quicker than sand beds
2	Quicker than sand beds; better drying; no sand replacement.
3	Lower operating costs compared to belt press, centrifuge. Capital costs lower. Good for small facilities (<500,000 gal/d)
4	Faster turnaround time than sand beds. Easier to remove sludge.
5	Quickly installed. Superior to sand drying, vacuum filters, and "bag" filter system.
6	Shorter drying time than sand beds.
7	Faster drying time than sand beds. No sand replacement. Easier to clean. More sludge processed. Less subject to clogged drainage.
8	Quicker than sand beds.
9	No sand replacement, no binding. Easy to replace tiles. Better for drying secondary sludge compared to sand beds.
10	-
11	No washout (weather and sand). Have the capability at this plant to convert to vacuum-assisted if needed.
12	Quicker than sand beds. Ease of handling. Can use heavy equipment. No sand replacement.
13	Less drying time. Less labor. Ease of operation. Not affected by weather.
14	More efficient than sand beds. Quicker turnover. Cost effective.
15	Quicker than sand beds. Can apply more sludge. Drains quickly.
16	Rains does not affect turnover time.
17	Fast drying time compared to sand beds. Quicker turnover.
18	-
19	Ease of cleaning. Quicker drying than sand beds. Cost effective.
20	Higher turnover rate. Ease of maintenance.
Dissatisfied	
1	-
2	Ease to clean. Ease to replace tiles.
3	-
4	No sand replacement.
5	-
6	None.
7	Faster in winter than sand beds.

Vacuum-Assisted Drying Beds

Identification of Plants

Table 12 lists users of vacuum-assisted drying beds including plant name, location, point of contact (POC), and telephone number. A total of 28 users were queried: 16 satisfied and 12 dissatisfied.

Plant Characteristics

Table 13 summarizes plant characteristics for both satisfied and dissatisfied users. Plant characteristics include plant capacity, treatment process used, sludge digestion process employed, and final disposal method.

The average capacity for responding plants was found to be 1.30 mgd. The range of flow for all of the plants responding to the question was from 0.15 to 8 mgd. Many of the VAB plants operate at levels well under capacity. For satisfied users, average flow was 1.1 mgd and the range of flow was from 0.15 to 4 mgd. For dissatisfied users, average flow was 1.5 mgd, ranging from 0.8 to 2.5 mgd.

In all, 23 users employed the activated sludge process, 2 used trickling filters, and single users used an oxidation ditch, a primary settling with alum addition, and a trickling filter and activated sludge combination.

Nineteen out of 28 plants using aerobic sludge digestion methods, processed sludge with VABs. Six plants used anaerobic digestion, and three did not digest the sludge prior to treatment (Table 13). Of the 16 satisfied users queried, 11 employed aerobic digestion, two employed anaerobic digestion, and three did not process their sludge. Eight dissatisfied users employed aerobic digestion and four used the anaerobic digestion process.

The most common final disposal method found in the survey was by land application. Of all of the plants surveyed, 16 used land application as the sole method of final disposal, 11 used landfilling, and one did not respond. Table 13 indicates that eight satisfied users employed land application and seven used landfilling for final disposal. Dissatisfied users included six who used land application, four who employed landfilling, one who combined land application with sand-bed storage, and one who used public distribution of the final product for eventual land application.

Sludge Characteristics

Table 14 summarizes the sludge characteristics found during the survey of VABs. The average percent of solids processed at all responding plants was found to be 2.6 percent, in a range from 1 to 7 percent. Satisfied users reported an average of 2.5 percent solids in a range from 1.5 to 4.25 percent. Dissatisfied users reported an average of 2.8 percent solids in a range from 1 to 7 percent.

Responding plants indicated an average target solids value of 15.8 percent in a range of 7 to 35 percent. Satisfied users had an average target of 15.4 percent solids, in a range of 8 to 35 percent, while dissatisfied users had an average target of 16.5 percent solids, in a range of 8.5 to 21.5 percent.

Table 12

Vacuum-Assisted Bed Contact Information

Plant ID	Location	Point of Contract	Telephone No.
Angola WWTP	Angola, IN	Rod Morrison	219-665-6806
Carterville WWTP	Carterville, IL	Randy Hess	618-985-2950
Centralia CORR CTR STP	Centralia , IL	Mike Lowry	618-533-7683
Chittenango WWTP	Chittenango, NY	Rod Severance	315-687-7314
City of Louisville	Louisville, CO	Wayne Ramey	303-665-7452
Fairfield STP	Fairfield, IL	Cloren Jourden	618-847-7026
Fort Stewart WWTP	Fort Stewart, GA	Vicki Howard	912-369-3391
Galena WWTP	Galena, IL	Jeff Ham	815-777-9315
Gaylord WWTP	Gaylord, MI	Dale Labelle	517-732-0750
Geneseo WWTP	Geneseo, IL	David Geary	309-944-2065
Granite City Steel STP	Granite City, IL	Ed Goodrow	618-451-4133
Hartsville WWTP	Hartsville, SC	Shelley Brand	803-332-2973
Jacksonville Beach Poll. Cont. Plant	Jacksonville Beach, FL	Donna Kalugniak	904-247-6294
Jonesborough STP	Jonesborough, TN	Wayne Campbell	615-753-6981
Lake Havasu	Lake Havasu, AZ	Doug Thomas	602-855-3999
Mackinac Island WWTP	Mackinac Island, MI	Ames Bugg	906-847-3278
Minooka WWTP	Minooka, IL	Rob Tonarelli	815-467-2142
Mount Dora WWTP	Mt. Dora, FL	John Youssy	904-735-7157
Nevada City WWTP	Nevada City, CA	John Drew	916-265-8668
Pekin WWTP	Pekin, IL	Don Gasper	309-477-2333
Peru WWTP	Peru, IN	Chuck Baker	317-473-7651
Plano WWTP	Plano, IL	Jim Atwell	312-552-8007
Ronceverte STP	Ronceverte, WV	James Jeffries	304-647-5717
Shelbyville WWTP	Shelbyville, IL	Laurence Quick	217-774-2712
Sullivan WWTP	Sullivan, IL	Bill Rankin	217-728-8241
Sylvania STP	Sylvania, GA	Tony Thompson	912-564-2358
Valle Lake	Valle Lake, MO	Bob Moore	314-586-3996
Woodstock WWTP	Woodstock, NY	Malcolm Camright	914-679-2356

Table 13

Vacuum-Assisted Bed Plant Characteristics

Plant ID	Plant Capacity (gal/d)	Treatment Process	Sludge Digestion Process	Final Disposal Method
Satisfied				
1	1,000,000	Activated sludge	Aerobic	Land application
2	750,000	Activated sludge	Aerobic	Landfill
3	150,000	Trickling filter	Aerobic	Landfill
4		Activated sludge	None	?
5	No Response	Activated sludge	Aerobic	Land application
6	1,000,000	Activated sludge	Aerobic	Landfill
7		Activated sludge	Aerobic	Landfill
8		Activated sludge (C-S*, STEP+)	Aerobic	Landfill
9	500,000	Activated sludge	Aerobic	Land application
10		Activated sludge (C-S*)	Anaerobic	Land application
11	4,000,000	Activated sludge	Anaerobic	Land application
12		Activated sludge (C-S*)	Aerobic	Land application-farming
13	750,000	Activated sludge	Aerobic	Land application
14	1,520,000	Activated sludge	None	Landfill
15	180,000	Activated sludge	Aerobic	Land application
16		Ox. ditch	None	Landfill
Dissatisfied				
1	2,100,000	Activated sludge	Aerobic	Land application
2		trickling filter/ Activated sludge	Anaerobic	Landfill
3	850,000	Activated sludge	Aerobic	Land application
4	1,500,000	Trickling filter	Anaerobic	Land application
5	No Response	Activated sludge	Aerobic	Landfill
6	2,500,000	Activated sludge	Aerobic	Landfill
7	1,000,000	Activated sludge	Aerobic	Land appl. and sand beds
8	1,100,000	Activated sludge	Aerobic	Land application
9				
10	Primary (Alum)		Anaerobic	Landfill
11	950,000	Activated sludge	Aerobic	Land application
12	2,000,000	Activated sludge	Anaerobic	Land application

*C-S : contact stabilization
+STEP : step aeration

Table 14

Vacuum-Assisted Bed Sludge Characteristics

Plant ID	Av. % Solids	Target Volumes	Generation Characteristics	Special
Satisfied				
1	3.50	12-14%	300 t/yr	Typical
2	2.00	11%	1 cu yd/1,000 gal/2 wks	Typical
3	2.00	10%	90 cu yd/yr	Typical
4	2.00	14%	1.2 t/d	Typical
5	2.45	8-9%	100 t/yr	Typical
6	-	-	59-60 t/6 mos	Cheese plant, BODs
7	2.00	15%	1.68 t/d	Metal bearing
8	1.5-2.0	10%	150-200 wt/mo	Typical
9	4.00	18%	96 t/yr	Typical
10	3-5 (4)	12-25% (18)	Unknown	Typical
11	1.25	12%	Unknown	Heavy metals (Zn, Cr, Cd)
12	1.50	18%	?	Typical
13	4.25	-	150,000 gal/mo	Typical
14	-	-	400-500 lb/d	Typical
15	-	35%	Unknown	Typical
16	1.50	30%	400 lb/3 days	Typical
Dissatisfied				
1	1.50	15-20%	2-4 mill gal/yr	High copper content
2	3.5-4.0	14-16%	10,000 gal/3.5 days	Typical
3	1.20	9%	750 cu yd/6 mos	Typical
4	7.00	20%	127.2 t/yr	Typical
5	-	-	Unknown	No response
6	1.00	-	Unknown	Typical
7	2.20	20%	Unknown	Typical
8	3.00	12%	Unknown	Typical
9	1.50	7-10%	Unknown	Heavy metals (Zn, Cu)
10	3.50	12%	Unknown	Typical
11	1.75	20-23%	45.5 t/yr	Heavy metals w/in standards (Cd, Pb, Zn, Cu, Mg)
12	5.00	-	400 t/yr	Typical

Although generation volumes for VAB installations were not available from every plant, Table 14 gives a range of values for 18 of the 28 respondents. Wedgewater estimates for generation volume were provided in various units to include dry tons per year, per week, or possibly per month, or as pounds or gallons per day or week.

Most of the plants were used to process typical municipal wastewater sludges. Special sludge characteristics varied with industries present in the system, including food wastes and heavy metals.

Dewatering System Data

VAB characteristics are summarized in Table 15. Wedgewater plants had only a few beds. (Eighteen plants reported only two beds.) Remaining plants reported one or three beds, and in one instance, five beds were identified. Satisfied users reported one one-bed system, 12 two-bed systems, two three-bed systems, and one five-bed system. Dissatisfied users reported three one-bed systems, seven two-bed systems, three one-bed systems, one three-bed system, and one five-bed system.

The size of all VABs generally ranged from around 400 to 1600 sq ft, a common dimension being 20 x 40 ft. VAB users in the satisfied category appeared, however, to average about half the size of dissatisfied users, that is about 400 to 800 sq ft as opposed to 900 to 1600 for dissatisfied users.

The oldest vacuum-assisted bed systems surveyed dated back to 1983. Most surveyed VABs were relatively new installations.

Although the predicted life cycle of most of the VABs was reported to be around 20 years, almost half of those queried did not know the life cycle of their systems, and four of the respondents indicated an actual performance cycle of 5 years or less (usually due to media damage or switching to another system).

Table 15, shows that 16 of the VAB dewatering operations surveyed were carried out inside buildings, over half of which were heated. Only 12 VAB operations were carried out in the open air, and two of these had roofs.

Design loading rates were reported in different units from plant to plant (Table 15). Conversion to standard measure showed that design loadings ranged from 0.6 to 7.6 lb/sq ft (one exception of 0.2 lb/sq ft) with average of 3.0 lb/sq ft. These figures were in good agreement with 1987 EPA design information.

Dewatering Performance Data

VAB performance can be measured by initial and final depths of sludge, drainage and air drying times, and dewatering cycle per week. Dewatering bed performance data for VAB are shown in Table 16. Initial sludge depths applied were generally in the range of 12 to 18 in., but applications of up to 30 in. were reported when sludge was applied in layers. In one instance, beds were loaded to 60 in. Final sludge depths were usually in a range of 2 to 4 in., although depths up to 12 to 18 in. were reported in four instances, where initial loadings were also greater.

Table 15

Dewatering System Data

Plant ID	Number of Beds	Size of Beds(1)	Construction Year	Predicted Life Cycle	Type of Exposure	Design Loading
Satisfied						
1	2	20 × 40 ft	1987	15-20 yr	Heated building	6000 gal/d/bed
2	2	20 × 40 ft	1988	20 yr	Building	Unknown
3	2	10 × 14 ft	1986	20 yr	Building	Unknown
4	1	20 × 40 ft	1985	10 yr	Heated building	1.0 lb/sq ft
5	2	20 × 40 ft	1986	20 yr	Heated building	30,000 gal/bed/d
6	3	20 × 40 ft	1983	Unknown	Heated building	Unknown
7	2	125 × 14 ft	1987	Unknown	Open	1.5 lb/sq ft
8	3	16 × 100 ft	1987	Unknown	Open	1.5 lb/sq ft
9	2	16 × 22 ft	1987	20 yr	Open air	5000 gal/bed
10	4	20 × 40 ft	1988	Unknown	Heated building	3.1 lb/sq ft
11	2	18 × 24 ft	1984	Unknown	Heated building	Unknown
12	2	20 × 50 ft	1983	Unknown	Roof	2.1 lb/sq ft
13	3	20 × 20 ft	1983	Unknown	Heated building	Unknown
14	2	25 × 50 ft	1986	Unknown	Open air	30,000 gal/bed/d
15	2	20 × 20 ft	1985	Unknown	Open air	3-4 in./bed; 4/wk
16	2	27 × 27 ft	1985	Unknown	Open	0.6 lb/sq ft
Dissatisfied						
1	5	30 × 30 ft	1984	20 yr	Open air	Unknown
2	3	26 × 86 ft	1985	Unknown	Open	2.4 lb/sq ft
3	2	20 × 40 ft	1987	Unknown	Building	Unknown
4	2	20 × 50 ft	1987	Unknown	Heated building	288 lb/sq ft/yr
5	2	20 × 20 ft	1983	Unknown	Building	3500 gal/4d/bed
6	1	20 × 50 ft	1986	Unknown	Open air	Unknown
7	1	35 × 60 ft	1984	Unknown	Building	2500 gal/bed
8	2	22 × 23 ft	1985	20 yr	Heated building	12 in.; 7,800 gal/bed
9	1	16 × 68 ft	1986	Unknown	Open air	22,000 gal/bed
10	2	20 × 40 ft	1984	Unknown	Roof	1.5 lb/sq ft
11	2	80 × 20 ft	1986	20 yr	Heated building	Unknown
12	2	20 × 40 ft	1985	Unknown	Heated building	8000-9000 gal/bed

Table 16

Vacuum-Assisted Bed Dewatering Performance Data

Plant ID	Depth of Sludge (in.) Initial	Final	Drainage Time	Air-Drying Time	Drying Cycle Time
Satisfied					
1	12	4	-	24 hr	5
2	12-14	2	3 hr	4-5 days	1/2 wk
3	12 (1st layer) (after 3 layers dewatered)	18	1.5 hr (1st layer; next 2 slower)	24 hr (each layer)	1
4	18	2-3	2+20*hr	0	5-7
5	24-30 (3-4 layers)	8-14	-	1-3 days	2
6	60	6-12	-	8-12 hr	3-4
7	18	6	3 days	3 days	1
8	10	2	1 hr	20 hr	2-3
9	18	2-4	12 hr	4 hr	4
10	12	3-4	0.5-1 hr	1-3 days	2-5
11	15-18	8-10	24 hr	24 hr	2-3
12	27	5	-	24 hr	3
13	12-18	4-6	8 hr	24 hr (summer)	4
14	18	2	24 hr	24 hr	5
15	12 (4 layers; 3-4 in. each)	3-4	1.5 hr	2 days	1/bed
16	8	1	<2 hr	3 days (w/heat)	2
Dissatisfied					
1	24-36	14	8-24 hr	3 days	1/bed
2	12	3	~3 hr	3 days	1.5-2
3	14	3-4	12 hr	12 hr	4
4	18	4-7	16 hr	2-7 days	1
5	16-18	3-4	-	3-4 days	1-2
6	18-24	4	-	24 hr	3-4
7	9-12	3-4	-	1 wk (4-5 days)	1
8	12	2-3	-	24-36 hr	3
9	24	4-5	1.5 days	2-2.5 days	1-3
10	24	12	-	4 days (summer)	1.5
11	12	4-5	-	1-3 wk	<1
12	12-24 3-4 wks (winter)	3-4 0.25	-	2 days	6

*2 hr low vacuum, 20 hr high vacuum

Drainage time for vacuum-assisted sludge beds was highly variable; estimates ran from as little as 1.5 hours to a couple of days (Table 16). Air-drying time was also highly variable; reported values ranged from 4 hours to a couple of weeks. It was apparent that respondents interpreted drainage time and air-drying time differently. Some plants used gravity drainage before vacuum drainage. Therefore, some regarded vacuuming time as drainage time and others regarded it as air-drying time. However, 1- to 2-day drainage by gravity and vacuum appears to be typical for satisfied users. Most VAB plants reported about one to four drying cycles per week.

Air-drying type and type of exposure (heated building, roof, or open air) were not closely correlated. Neither building or even-heated building appeared to reduce the air-drying time as compared with open-air type. Buildings did appear to protect the bed from precipitation and (in winter) from freezing.

Polymer Data

A variety of polymers are used to pretreat sludges before dewatering by VABs (Table 17). Polymer dosage for WBs was reported in several units, either by volume or by weight. The most common polyr type was liquid emulsion, cationic polymer, which is sometimes bought as a powder and is later mixed with water at a plant. Typical polymer dosages were estimated at 4 to 23 lb per dry ton of sludge. The 23 pounds per dry ton of sludge was about twice the upper value given in the 1987 USEPA design manual. Polymer overdosing may cause operational difficulties as well as higher costs: longer drying time and more media clogging due to stronger adhesion.

Polymer costs are also shown in Table 17 and were reported to range from $1.50 to $2.00 per pound, although prices were also reported for 55-gal drums.

Cleaning Data

VABs are most often cleaned with high pressure water hoses applied after each cycle (Table 18). The duration of the cleaning cycle varies from about 30 min to 3 or 4 hours, but appears to average about 1-1/2 hours per 1000 sq ft bed. Some plants used hypochlorite, hydrochloric acid, or muriatic acid to remove clogging materials and biological growth. One plant used Polyslov, a proprietary cleaning product, for every cleaning. Because VABs have many fine pores and are thus susceptible to clogging, chemical treatment of the beds is often recommended. Another method used was back flushing. However, since the media is a bonded material, VAB back flushing is not as effective as doing a sand-filter back wash.

Sludge Removal Method

Sludge removal methods for VABs are listed in Table 19. Sludge removal for this system usually employs a front-end loader. Some plants use plastic-covered blades to minimize tile damage. Table 19 shows the variety of loaders used to remove sludge from VABs. The "Bobcat" was the most popular loader. Loader weights for vacuum-assisted beds were generally over 1000 pounds, and a value of up to 2 tons was reported in one instance.

Table 17

Vacuum-Assisted Bed Polymer Data

Plant ID	Name of Polymer	Manufacturer's Name	Polymer Dosage	Cost of Polymer
Satisfied				
1	P456	Chemco	5-6 gal/bed	$ 756/55 gal drum
2	K-133 L	Stockhausen	5 gal/bed/load	$ 65/5 gal
3	Calgon	Genetic Research	1.5-2 gal/bed	$ 1.75/lb
4	Stafloc 128	-	2.5 lb/ton	$ 3/lb
5	Praestol K133-L	Stockhausen	0.5 lb/1000 gal	$ 1.90/lb
6	K-133	Stockhausen	3 gal/bed	Unknown
7	ES-12	Env. Specialty	4.6 gal/ton	Unknown
8	Polypure-E-149	S&S	6 gal/bed	$ 1.37/lb
9	Praestol K133-L	Stockhausen	1 gal/bed	$ 2.10/lb
10	K-122L	Stockhausen	2-2.5 gal/bed	$ 1.53/lb
11	KC 135	Oldurich	Unknown	Unknown
12	Secodyne 777	Secodyne Corp.	10 gal/ton	Unknown
13	SPC 8180	Petrolite	Unknown	$ 1.50/lb
14	Praestol K133-L	Stockhausen	1 gal/bed	$ 1.88/lb; $ 75/5 gal
15	K-133 FL	Stockhausen	Unknown	$ 84/5 gal
16	-	(Local)	-	$ 2/lb
Dissatisfied				
1	Praestol K-122L	Chemtronics	2 lb/500 lb	Unknown
2	Chem T.L	Chemtrtol	100 gal/bed (10%)	$ 0.20/gal (10% liquid solution)
3	Magnafloc 1598-C	American Cyanamid	2.5 gal/bed	$ 2.00/lb (est.)
4	Praestol K133-L	Stockhusen	3 gal/bed	$ 1.79/lb
5	Unknown	Nalco Chem Co.	Unknown	Unknown
6	Magnafloc	American Cyanamid	2.5-3 gal/bed	Unknown
7	Praestol K133-L	Stockhausen	Unknown	$ 2.10/lb
8	K-133	Stockhausen	3/4 gal/bed	$ 13.0/gal
9	Unknown	Waterwise	5-7 gal/bed	$ 1.66/lb
10	1596-C	American Cysnsmid	17 lb/ton	$ 1.78/lb
11	Praestol JL33	Stockhausen	Varied	$ 14.0/gal
12	Unknown	Water Products	1 gal/ton	$ 715/55 gal drum

Table 18

Vacuum-Assisted Bed Cleaning Data

Plant ID	How Cleaned	How Often	How Long
Satisfied			
1	High-press. water hose	Daily	3 hr
2	Garden hose	Every 2 wk	1 hr
3	High-press. water hose	Weekly	45 min/2 beds
4	High-press. water (120psi)/chloride	Daily	2.5-3 hr
5	Washing	Each cycle	5 hr
6	High press. cavity pump	Each cycle	0.75-1.5 hr
7	High-press. water; chloride/3 mo	Each cycle	1-1.5 hr
8	High-press. water; HCL-1/3-6 mo	Each cycle	2 hr
9	High-press. water hose	Each cycle	30 min
10	High-press. water	Each cycle	2 hr/bed
11	High-press. hose/monthly bleach	Each cycle (hose)	1.5 hr/bed
12	Tap water; 6 gal chloride sol/6 mo	Each cycle	1 hr
13	High-press. water hose	Each cycle	45 min
14	High-press. water hose	Daily	30 min
15	High-press. hose/degreaser	1/2 mo	2 hr
16	High-press. water; polysolv + chlorine/mo	Each cycle	2 hr
Dissatisfied			
1	Jet hose (100 psi)	Daily	No response
2	High-press. water (80psi); chlorine/mo	Each cycle	1-1.5 hr
3	High-press. wash	Each cycle	1 hr/bed
4	High-press. water hose	Each cycle	2 hr
5	Water hose	Every 4-5 days	No response
6	No response	No response	No response
7	No response	No response	No response
8	High-press. hose; Chlorine	1/3-4 wk	1.5 hr/bed
9	Back flush/water hose	Each cycle	10-12 hr
10	High-press. water/hypochloride	Each cycle	4 hr/bed
11	High-press. water hose	Each cycle	4 hr
12	High-press. water hose	Each cycle	15-20 min

Table 19

Vacuum-Assisted Bed Sludge Removal Method

Plant ID	Front-End Loader Type	Weight
Satisfied		
1	Bushhog	1900-2100 lb
2	Bobcat	Unknown
3	None - wheelbarrow & hand shovel	-
4	Bobcat	2000 lb
5	Bobcat	1000 lb
6	Bobcat	Unknown
7	Loader, small Case	Unknown
8	Bobcat, model 742	-
9	None - hand shoveled	-
10	John Deere II-2040	>4000 lb
11	Case	1500 lb
12	John Deere, model 24A	6000 lb
13	Bobcat	2000 lb
14	Bobcat	800-1000 lb
15	Bobcat	Unknown
16	Shoveling & loader	-
Dissatisfied		
1	Bobcat	Unknown
2	Small Bobcat	Unknown
3	Gehl Skidsteer Loader	<1500 lb
4	Skidsteer Loader	~1500 lb
5	Bobcat	1500 lb
6	International Tractor	2000 lb
7	Kubota Tractor	2000 lb
8	Bobcat	2300 lb
9	Bobcat	1000 lb
10	Bobcat	

Unit Construction Costs and Warranty

Limited construction cost data for VABs is shown in Table 20. Direct comparison of cost data was difficult because some plants had VAB buildings and others were converted from sand-drying beds. Construction costs per square foot ranged from $30 to $70.

Table 20 includes warranty periods for VAB installations. Typically a period of 1 year was reported.

Problems

Problems and their remedies encountered with VAB use are shown in Table 21. The common complaints about VABs related to media damage, epoxy failure, wet sludges, a perception that system cleaning was too labor-intensive, and air pumping and drainage problems (clogging from solids accumulation). The VAB pores are finer than the wedgewater bed's, making solids capture by VAB better than by WB, but also creating a clogging problem. When the media was clogged, additional air drying was required in place of drainage. Wedgewater systems had fewer mechanical troubles than did VABs. Wet sludge might be a problem if the vacuum-dewatered sludge was not sufficiently air dried to meet the target solid content. If sludge-detention time would be increased, area requirement would also increase.

Advantages of the System

The advantages of VAB systems are listed in Table 22. Plant operators often compared VAB systems to sand-drying beds. VABs require less area than do sand-drying beds. Since sludge-drying detention time on a VAB was shorter than that on a wedgewater bed, the area requirement would be reduced accordingly. Among the advantages the survey noted were better dewatering properties (by vacuum), less sludge volume (by comparison with the sludge dewatered on either a sand or wedgewater bed for the same dewatering time), easier storage and transportation, less weather dependence, and less dependence on manual labor.

Field Visits

One field visit was made to each of the two surveyed sludge dewatering systems to personally interview plant operators and photograph the systems. Site interviews were similar to the phone surveys.

Wedgewater Bed

The wedgewater bed field survey was conducted at the Mt. Gretna Authority, located in Mt. Gretna, Pennsylvania. The 200,000 gal per day (gpd) capacity plant, built in 1940, presently operates at about half capacity and uses a trickling filter wastewater treatment process as well as Imhoff tank sludge processing. The sludge is produced by a seasonal community of 700 homes, of which half contain year round residents. It is a typical municipal waterplant, except for the water's high copper content. The operator was unable to provide quantities for generated sludge, since he has only recently been required to measure it.

Table 20

Vacuum-Assisted Bed Unit Construction Costs and Warranty

Plant ID	Construction Costs	Warranty Period
Satisfied		
1	$345,000 (inc. bldg.)	1 yr
2	Unknown	Unknown
3	$430,000 (inc. bldg.)	1 yr
4	$ 100,000	Unknown
5	Unknown	Unknown
6	Unknown	Unknown
7	Unknown	Unknown
8	Unknown	Unknown
9	Unknown	1 yr
10	Unknown	Unknown
11	Unknown	1 yr
12	Unknown	Unknown
13	Unknown	Unknown
14	$70-75,000/beds, including pumps filter, controls	2 yrs
15	Unknown	1 yr
16	$42/sq ft	Unknown
Dissatisfied		
1	$69,473/beds	1 yr
2	Unknown	1 yr
3	Unknown	2 yrs
4	Unknown	1 yr
5	$300,000/2 beds	6 mo
6	Unknown	1 yr
7	$115,000/1 bed	Unknown
8	$ 60,000/beds, including pumps filters, controls	Unknown Unknown
9	Unknown	1 yr
10	Unknown	Unknown
11	Unknown	1 yr
12	Unknown	1 yr

Table 21

Vacuum-Assisted Bed Problems and Remedies

Plant ID	Problems	Remedies
Satisfied		
1	Overloading; sludge was too wet when removed 6000 g/b/d	Reduce sludge load from 9 to 15,000 g/b/d to
2	Electric timer problems	Replaced timer
3	Epoxy seals around edge; polymer pump problem	Repairs
4	Cleaning is time-consuming	-
5	Media plates wear out	Replace plates
6	Sludge binds media; solids accumulation	Clean each bed with muriatic acid twice/yr
7	Joint (perimeter) rupture; gate bends	Caulking; need bracing
8	Labor more than expected	-
9	Freezes in winter, sludge stays wet; tiles blades scarred	Use hand shovel to remove sludge w/rubber
10	Drainage pipe clogging	Periodic cleaning
11	Does not use vacuum; sludge compacts under media and labor intensive to clean	Use gravity filtration only
12	Joint crack	Patch
13	Media grout loosened; media surface damage	Repairs; one person operates Bobcat & keeps tires clean
14	Vacuum pumps clog	Backwash & degrease; use without vacuum pump; filtration only
15	Sand finish coming off tiles	Replace finish on tiles
16	Leaky bed-negating vacuum applied	Under negotiation

Table 21 (Cont'd)

Vacuum-Assisted Problems and Remedies

Plant ID	Problem	Remedy
Dissatisfied		
1	Plates corrode; loss of vacuum space b/c of epoxy failure; lengthy drying time; wet sludge	Repaired plates; replaced system with centrifuge
2	W/o cover, rain problem; wish to be able to backwash	-
3	Must use high press. washer to clean tiles in order to get good dewatering; labor intensive; media plates crack	Replace plates; Epoxy patches
4	Wet sludge; loss of nitrogen-air drying; loss of tiles due to epoxy failure; only occasional use	Bought sludge hauler that injects wet sludge into ground-saves nitrogen; repaired tiles
5	Hard to start vacuum; sludge in check valves system causing flooding; inadequate dewatering	Reroute discharge; epoxy leaks in vacuum
6	Epoxy disintegrates; media binds - solids accumulation; inadequate drainage-wet sludge; labor intensive	Resurface tiles; use bleach or acid to clean; use sand beds as back-up when media fails
7	Surface of tiles fragile and wears out	Use only as needed; being replaced by belt press
8	Surface flakes; epoxy failure; labor intensive	Replace sand; enrich epoxy
9	Tiles wear out	Carborundum blade on bobcat; epoxy, add sand/gravel
10	Alum. sludge takes longer time	-
11	Inadequate dewatering; polymer feed pump problems; epoxy failed	Replace epoxy; repaired pump

Table 22

Vacuum-Assisted Bed Advantages

Plant ID	Advantages
Satisfied	
1	Less volume to move when sludge is dewatered; year-round use in most weather
2	Produces dry sludge even in cold weather
3	Not weather dependent
4	Dry faster and enclosurable; minimal maintenance
5	Less labor intensive than sand beds; more capacity; less storage space required
6	Fast turnover rate; dry enough to handle easily
7	Little maintenance
8	Polymer; expedite dewatering/easy removal
9	Fast turnover rate
11	Not weather dependent; can be stored; no odor if digested properly
10	-
12	Less weather dependent; quick dewatering
13	Fast turnover rate; ease of sludge removal; drier product
14	Cake dries faster (24 hours)
15	Good drying
16	Fast dewatering
Dissatisfied	
1	-
2	Quick, easy removal; easy cleaning
3	Good dewatering
4	Good when land is insufficient and temperature is hot (summer); sludge can be stored
5	-
6	-
7	Can use in bad weather
8	Less sludge volume (for small plant land applying)
9	-
10	-
11	Not weather-dependent
12	Removes large amounts of water

The primary sludge has a solids content of approximately 6 percent. The target solids content following dewatering is about 20 percent (sometimes more). Sludge is applied approximately 10 in. deep to the single 600-sq ft wedgewater bed, which was converted from an old sand bed by plant personnel using Gravity Flow Systems literature. The design loading rate was worked out by plant personnel. The bed is open-sided and covered with a roof, which also shelters an old sand bed used to store dewatered sludge. To comply with Department of Environmental Resources requirements, the final disposal method was changed from land application to independent contract. (A hauler now removes the dewatered sludge from the sand bed.)

The dewatering process only shrinks the applied sludge by one inch since it is mostly dewatered by the time it reaches the media. Separation is already evident when the sludge/polymer mixture comes out of the discharge line, to the extent that the sludge must be spread around the media to get an even layer. The sludge dries in about 7- to 10-day drying cycles, and is currently removed by hand shoveling, which takes about 1-1/2 days. The plant plans to buy a Kubota front-end loader for future removal.

The polymer used by the plant is Praestol K133L, which is sold by Pollu-Tech of Richboro, Pennsylvania. The polymer is fed to the sludge at a dosage of 10 strokes/minute, or 20 gal of 0.2 percent polymer solution fed to 1000 gal of sludge. This application costs about $75 for a 5-gal pail, of which one-fourth (1.25 gal) is used for each loading.

Cleaning the 1-ft square polyurethane wedgewater tiles is done every cycle with a high pressure pump, a procedure requiring about 1 hour. So far, the plant has not experienced clogging of the underdrains.

The operator and plant engineering personnel converted the existing sand bed to a wedgewater bed by pouring concrete sides, installing the concrete slab bases and drain configuration, placing the media on top, and connecting a polymer feed pump to the sludge discharge line. This work cost about $7000, and the media cost about $30,000. The media consists of orange, slotted tiles raised on feet that sit on the concrete slab base to allow underdrain clearance. The manufacturer warranties this medium for 1 year. The operator pointed out that the drain placement is crucial. This system has eight drains: four lateral drains on each side of a central drain rib.

The Mt. Gretna Authority is a satisfied WB user. This wedgewater bed system has given no problems since its installation. The operator noted that special advantages of the WB over the sand bed are the ease of cleaning, and the absence of sand replacement. Moreover, one wedgewater bed replaced five sand beds; i.e., the WB can handle much greater loading than the sand bed. Although the WB also dries sludge more quickly, the Mt. Gretna operator stated that this factor may be attributed solely to the polymer. Tests run comparing a sand bed to a WB without polymer showed that the WB dried sludge only slightly faster than the sand bed.

Vacuum-Assisted Bed

The field visit to the VAB system was conducted at the Woodstock Wastewater Plant located in Woodstock, NY. The plant operator is Mr. Malcolm Camwright. The activated sludge process plant, built in 1985 and designed for 237,000 gpd, presently processes only about one-third of the generated wastewater. The plant does not employ digestion prior to dewatering. Dewatered sludge is presently disposed of at a landfill.

The raw sludge, which is typically municipal, is approximately 1 to 2 percent solids. The plant generates a volume of approximately 3000 to 4000 lb of dry solids per month, depending on the season. The target solids content following dewatering is 20 percent. The sludge is applied to two enclosed 24.5 ft x 18 ft VABs, each holding 3650 gal, to a depth of 15 in. The design loading rate (which the operator found unworkable) is substantially higher than the actual loading rate. Once the sludge is applied, it takes about 3 hours for the free water to drain off. The vacuum is left on for 24 hours, and the sludge is then air dried in the heated building for a total drying time of 2 to 3 days. One bed has 3 to 4 drying cycles per week, while the other is slightly slower at 2 cycles per week.

The Woodstock treatment facility uses a polymer supplied by East Coast Environmental of Montgomery, NY. The polymer, #BEG 44505, comes in 50-lb bags, which cost about $170 each. The polymer is diluted at 1.5 lb/140 gal of water, and fed to the sludge at a rate of 7 parts per million (ppm).

The epoxy-bonded media tiles in the vacuum-assisted beds are cleaned every cycle with a high-pressure hose, followed by a chlorine wash. The hose is then set at a higher pressure for a second wash. On occasion, a polymer remover is also used to prevent clogging. Finally, the dewatered sludge is removed from the tiles by hand shoveling. (Use of the plant's Waldon front-end loader was found to damage the media.)

Specific information on unit construction costs of the beds was unavailable since they had been installed with the rest of the plant. However, tile replacement costs were $300/tile. Warranty information was unavailable. White and Company, of Charlotte, NC, supplies the media tiles.

The plant operator was generally satisfied with the present operation and performance level of the vacuum-assisted system; however, he pointed out several disadvantages associated with the system. Costs of cleaning, polymer, propane building heaters, and tile replacement make the system operation relatively expensive. According to the operator, of the two VABs, one does not work properly, and the other bed has lost some efficiency, although it still performs satisfactorily. The operator further stated that the concrete slab beneath the slower of the two beds may have cracked.

Overall, the operator feels that VABs are an improvement over sand beds. However, since this plant cannot handle a higher loading rate the municipality is considering more efficient and cost effective alternatives.

4 CONCLUSIONS

A telephone survey was carried out for both wedgewater and vacuum-assisted sludge drying beds. The survey helped to divide users into satisfied and dissatisfied groups of wedgewater and vacuum-assisted dewatering technologies. Survey results indicate that the wedgewater system can provide essentially the same service as the vacuum-assisted beds, but with fewer operational and maintenance problems.

Wedgewater Bed

Generally, wedgewater bed system operators were very satisfied with the system's sludge-dewatering capacities. Most dissatisfied users indicated that the problems were due to structure design difficulties, which include inefficient drainage, uneven distribution of sludge on the beds, and difficulty of underdrain cleaning. However, one reported media shrinkage and another reported torn-apart media. Since most of the system's users interviewed landfill dewatered municipal sludge, they require final solids of about 15 to 20 percent. The wedgewater system provides this degree of dewatering with about one drying cycle per bed per week.

Most system problems were associated with inadequate media cleaning, front-end loader damage to the filter media, or engineering errors. It appears that, with proper design, installation, care, and maintenance during operation, the beds will have a long life, and will require underdrain cleaning only once or twice a year. To prevent media damage, most operators recommend using a nonskid-steering front-end loader equipped with a bucket with a polyurethane blade. Although most WBs were open-air operations, use of a translucent roof or canopy was recommended for areas that receive larger quantities of precipitation, or where freezing occurs. WB solid capture was less than VAB, but additional solid loading of WB filtrate to the head of a plant did not adversely affect plant performance.

Generally speaking, WBs were easier to operate and maintain, and provided a quicker turnover rate than sand beds. WBs showed fewer problems with media and underdrain clogging when high-pressure hoses were used to clean the tiles, and when tiles were kept free from damage.

Vacuum-Assisted Bed

As a rule, there are more difficulties associated with VAB performance than with WB performance, even though the number of VAB drying cycles per week is generally higher than the number for wedgewater beds. Some surveyed operators stated that the vacuum actually pulled sludge into the media, thus aggravating media-clogging problems. These operators no longer use the vacuum component, letting the system function like a wedgewater bed system. When vacuum is not used and water is only drained by gravity, the system performs more effectively.

Plants that chose VABs over WBs were smaller in size and generally required a lower target solids rate because their most common disposal method is land application. However, satisfied VAB users were divided nearly evenly between disposal by land application and by landfilling.

Contrary to expectations, VABs did not achieve higher solid contents than WBs. A common complaint against VABs was that the sludge was not "bladeable" in the predicted time, and therefore required long drying. This problem resulted from inadequate drainage caused by media binding and/or underdrain clogging, and to media destruction caused by front-end loader or epoxy failure. Plant operators recommended that front-end loader buckets be equipped with polyurethane blades to prevent damage. Skid-steering loaders also appear to damage VABs. Adequate tile cleaning also appears to be more difficult for VABs than for WBs.

VAB system advantages include a faster turnover rate than sand or wedgewater beds, the ability to operate year-round due to the system's building enclosure, and less space requirement. In total, VABs dewater more efficiently than sand beds, but do not perform as well as wedgewater beds do when air drying is required. However, VABs are still more effective in achieving a target solid range of 11 to 13 percent, because only vacuum can reach these high concentrations.

For these reasons, a decision was made to build a wedgewater bed rather than a vacuum-assisted bed, along with a reed bed at Fort Campbell to demonstrate and further compare these dewatering technologies in an Army-installation environment.

METRIC CONVERSION TABLE

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 sq ft	=	0.093 m^2
1 cu ft	=	0.028 m^3
1 lb	=	0.453 kg
1 ton	=	907.1848 kg
1 gal	=	3.78 l

APPENDIX: Sample Questionnaire

DEWATERING SYSTEM: ______________________________

Satisfed ______________ Unsatisfied ______________

Name of Plant: ______________________________

Address: ______________________________

____

____

____

P.O.C.: ______________________________

Phone No.: ______________________________

1) PLANT CHARACTERISTICS

Capacity ______________________________

WW Treatment Process ______________________________

Sludge Digestion Process ______________________________

Sludge Disposal Method ______________________________

2) SLUDGE CHARACTERISTICS

% Solids (Raw Sludge) ______________________________

Target Solids Content ______________________________

Generation Volume (Dry Solids) ______________________________

Special Chemical Characteristics, if any (i.e., Char. that make sludge atypical from municipal sludge)

____

____

____

3) DEWATERING SYSTEM

Number of Beds____________________________

Size of Beds (1)____________________________

Year Constructed____________________________

Predicted Operational Life Cycle____________________

Replacement of Media Cycle (if any VADB)______________

Type of Exposure (e.g. open air, greenhouse)______________

Manufacturer____________________________

Design Loading Rate____________________________

4) DEWATERING PERFORMANCE

Initial Sludge Depth____________________________

Final Sludge Depth____________________________

Number of Sludge Layers____________________________

Drainage Time____________________________

Air Drying Time (if any) (i.e. Vacuum cycle & evaporative phase - if any).____________________________

Total Dewatering Time (# drying cycles per wk)______________

Filled w/ water? (VADB only)

Yes__________ No__________

5) POLYMER DATA

Polymer Name____________________________

Manufacturer____________________________

Polymer Dosage____________________________

Cost____________________________

6) CLEANING

Method(s)____

Frequency____

Duration____

7) SLUDGE REMOVAL

Method (e.g. loader, tilting metal trays - ww only)_________

Front End Loader Type______________________________

Weight____

8) UNIT CONSTRUCTION COSTS

Warranty Period__________________________________

9) PROBLEMS

(e.g. Media failure, Solids accumulation beneath media)

10) REMEDIES

11) ADVANTAGES OF SYSTEM

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